SDA Bocconi
SCHOOL OF MANAGEMENT

Monitoring the efficiency and effectiveness of EPR schemes in Europe

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1. Introduction

The Extended Producer Responsibility (EPR) framework has long been a central element in European waste management policies, aiming to enhance the recycling and recovery of packaging materials through the involvement of Producer Responsibility Organizations (PROs). The European Union has recently updated its Extended Producer Responsibility (EPR) framework to enhance the recycling and recovery of packaging materials, involving Producer Responsibility Organizations (PROs) in the process. In February 2025, the EU's Packaging and Packaging Waste Regulation (PPWR) entered into force, replacing the previous Packaging and Packaging Waste Directive (PPWD). This regulation aims to reduce packaging waste, promote reusable and refillable systems, and ensure all packaging is recyclable by 2030. It sets specific recycling targets, including 80% for ferrous metals, 75% for paper and cardboard, and 55% for plastics. Additionally, there are binding recycled content targets for plastic packaging and restrictions on certain single-use packaging items. A 90% collection target for plastic beverage bottles and cans by 2029 is also mandated, supported by deposit return systems. These measures reflect the EU's commitment to a circular economy, emphasizing waste prevention, higher recycling rates, and the use of recycled materials in packaging.

In light of the evolving regulatory landscape, the ongoing assessment of waste management systems is particularly relevant, as new policies and regulations continue to reshape the responsibilities of producers, the efficiency of recycling operations, and the overall sustainability of packaging waste management. With stricter targets and expanded regulatory measures, it is crucial to evaluate how different **packaging waste management schemes** —such as EPR based on Producer Responsibility Organizations, Deposit Return Systems (DRS), and public waste management with **tax-based** financing—adapt to these changes and contribute to achieving the EU's circular economy goals. Understanding the effectiveness of these systems in meeting recycling targets and reducing environmental impact is essential for policymakers, industry stakeholders, and researchers striving to optimize waste management strategies across Europe.

In the initial study "**Screening the Efficiency of Packaging Waste in Europe**" (Croci et al., 2021), the performance of EPR schemes was assessed using Key Performance Indicators (KPIs) that evaluated both cost-efficiency and recycling effectiveness. This analysis, which focused on 21

European PROs, provided valuable insights into the relationship between recycling outcomes and the associated financial costs. However, as the waste management landscape evolves, so too must the methods used to assess system effectiveness. This study aims to **extend the scope of the previous research** by integrating a broader range of waste management systems operating within Europe, including DRS and public waste management with tax-based financing, alongside traditional EPR schemes based on PROs.

The present work builds upon the methodological foundation established by Croci et al. (2021) by incorporating novel data collected on the operational performance and fee structures of various waste management systems, including PROs, DRS, and systems utilizing taxation to incentivize recycling behaviors. This expanded analysis allows for a more comprehensive understanding of the diversity in performance across European waste management systems and provides a more holistic view of the **efficiency** and **effectiveness** of alternative regulatory frameworks.

A key innovation of this report is the introduction of a dynamic framework for the **ongoing monitoring of EPR scheme performance**, utilizing an updated set of KPIs. This approach will facilitate the annual tracking of key indicators, allowing for real-time assessment of system effectiveness and the identification of trends and areas for improvement. In alignment with the increasing call for transparency in waste management, the updated KPIs will be made publicly available through **interactive maps**, offering stakeholders—from policymakers to the public—access to real-time data and enhancing accountability. This innovation aims to foster greater transparency, drive continuous improvement in waste management systems, and promote evidence-based decision-making across Europe.

By incorporating new data, extending the scope of analysis, and providing a continuous monitoring framework, this study seeks to advance the understanding of how diverse waste management systems contribute to environmental goals, ultimately guiding the development of more effective and sustainable waste management policies across Europe.

2. Method

This study builds on a comprehensive framework for assessing the performance of Producer Responsibility Organizations (PROs), Deposit Return Systems (DRS) and public waste management with tax-based financing. The evaluation leverages two primary performance indicators (KPIs): the recycling KPI, which measures the proportion of material recycled relative to the amount placed on the market, and the cost KPI, which assesses the economic efficiency of each system by calculating the cost per ton of recycled material. These KPIs are computed for both PROs and DRS, enabling direct assessments of their operational effectiveness.

The analysis incorporates a classification of EPR scheme characteristics, considering market structure, operational responsibility, and system scale. Market structure distinguishes between non-competitive and competitive compliance schemes, while operational responsibility categorizes whether local authorities, private contractors, or a combination of both manage collection and recycling. Systems are further classified by their market dimension, based on the population served.

For PROs, the cost KPI considers the average fee charged per ton of material placed on the market and the actual quantities recycled. For DRS, the cost KPI includes handling fees (both manual and via Reverse Vending Machines) and administrative costs, adjusted for the share of materials collected through different methods. These KPIs are normalized using min-max scaling to ensure comparability across systems. The cost components for both PROs and DRS systems are carefully detailed in the next sections.

Finally, the study integrates data from multiple sources, including annual reports from PRO-Europe, EXPRA, and various national and institutional publications, creating a robust dataset that spans multiple years (2010-2024) and covers a wide range of materials and collection strategies across European countries. The results of the analysis are visualized in interactive maps, allowing for the ongoing monitoring of EPR scheme performance across Europe. The map in Figure 1 visually represents the countries in Europe evaluated in this report, distinguishing between Producer Responsibility Organizations (PROs), Deposit Return Systems (DRS) and public waste management with tax-based financing.

2.1 Classification of waste management compliance schemes

In Europe, the regulatory landscape for packaging waste management involves a mix of Producer Responsibility Organizations (PROs), Deposit Return Systems (DRS), and public waste management with tax-based financing, with countries adopting varying combinations of these approaches (see Figure 1). Countries with both EPR based on PROs and DRS evaluated in the work include Sweden, Norway, Estonia, Denmark, Finland, Lithuania and the Netherlands. DRS systems are specifically focused on beverage packaging, such as bottles and cans, and are therefore complementary to broader EPR schemes, which cover all types of packaging materials. EPR schemes manage the overall collection, recycling, and recovery of packaging waste, while DRS targets a specific subset of packaging, typically related to drinks, providing an additional layer of recycling for these items.

Countries with both EPR and Tax are Lithuania, Latvia, while in Croatia DRS and public waste management with tax-based financing co-exist. Finally, Hungary transited from a public waste management with tax-based financing to a EPR scheme based on a single PRO between 2022 and 2023. In Lithuania and Latvia, the tax system is complementary to the EPR scheme, meaning that the tax on packaging is applied alongside the EPR framework, reinforcing the incentives for producers to manage their packaging waste responsibly. The tax is typically levied based on the weight or material type of packaging, while the EPR scheme ensures the recycling and recovery of materials through PROs. However, Hungary took a different approach until 2022, with its environmental product charge (tax) functioning as an alternative to the EPR scheme. The tax, applied to packaging materials, was not integrated into a broader EPR scheme but operated as a standalone mechanism for managing waste. Since 2023, Hungary has transitioned to an EPR scheme for packaging waste management, with the environmental tax now playing a marginal role, mainly targeting plastic bags.

In summary, DRS is always specific to a subset of materials, typically beverage packaging—and serves as a complement to broader EPR schemes, which cover a wider range of packaging materials. Taxation mechanisms, on the other hand, may either function complementary to EPR (as seen in Lithuania and Latvia) or previously serve as an alternative to EPR (as in Croatia and in Hungary until 2022).

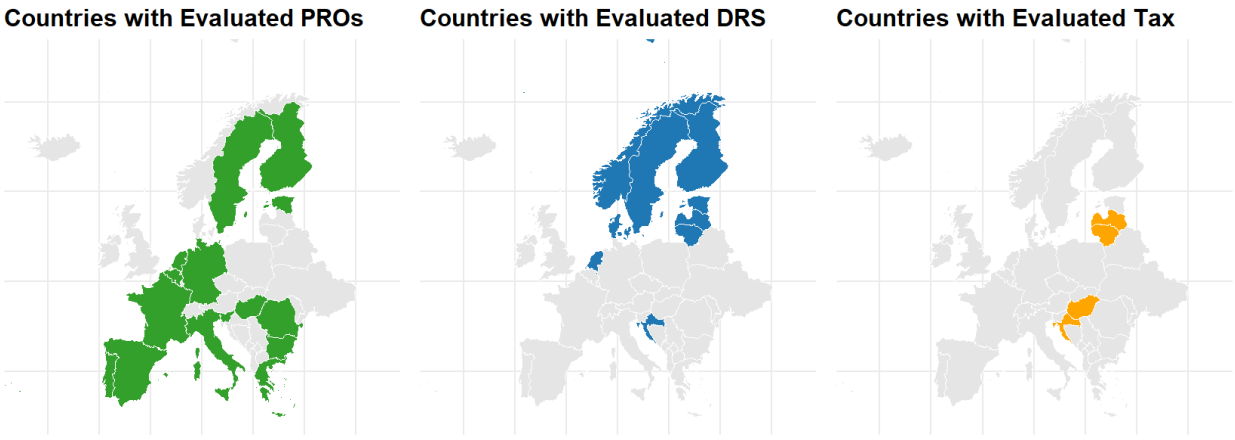


Figure 1: *Map of EU countries by each waste management scheme evaluated in this report*

2.2 Data

2.2.1 EPR fees

The data on the level of the EPR fees applied year-by-year by each PRO has been gathered from the reports provided by PRO-Europe (available from 2010 to 2024). From these sources it was possible to create a dataset for the period 2010-2024 for 35 different PROs, containing fees for each material (aluminum, biodegradable, composite, glass, paper, plastic, steel, wood), and even sub-materials, distinguished between household and commercial or industrial packaging, if applicable.

The data on the operational characteristics of EPR scheme, including the classification on PROs' financial and operational responsibility, the number of inhabitants covered, the amount of packaging waste placed on the market, recovered and recycled by material and the type of collection strategy adopted in the country, are gathered from the documents of the reporting activity of EXPRA, available from 2014 to 2023, and from Croci et al., (2021). As EXPRA provides information only on the PROs associated to EXPRA, data for PROs which are associated to PRO-Europe or which are independent from any pan-European organization have been gathered by inspecting the operational reports of each PRO, when available (such as Ponto Verde, 2019; CITEO, 2019) and by National institutional sources (such as the packaging Portal of the German

Federal Ministry of the Environment). The quantitative and qualitative information collected have been used in our analysis to summarize PROs' performance and heterogeneity.

Note that for Germany, detailed fee data was available from DGP's fee calculator. This data has been used as a proxy of the country-level average fee. Furthermore, given lack of PRO-specific data on recycling rates by material, the analysis for the German PRO's system focuses on country-level results.

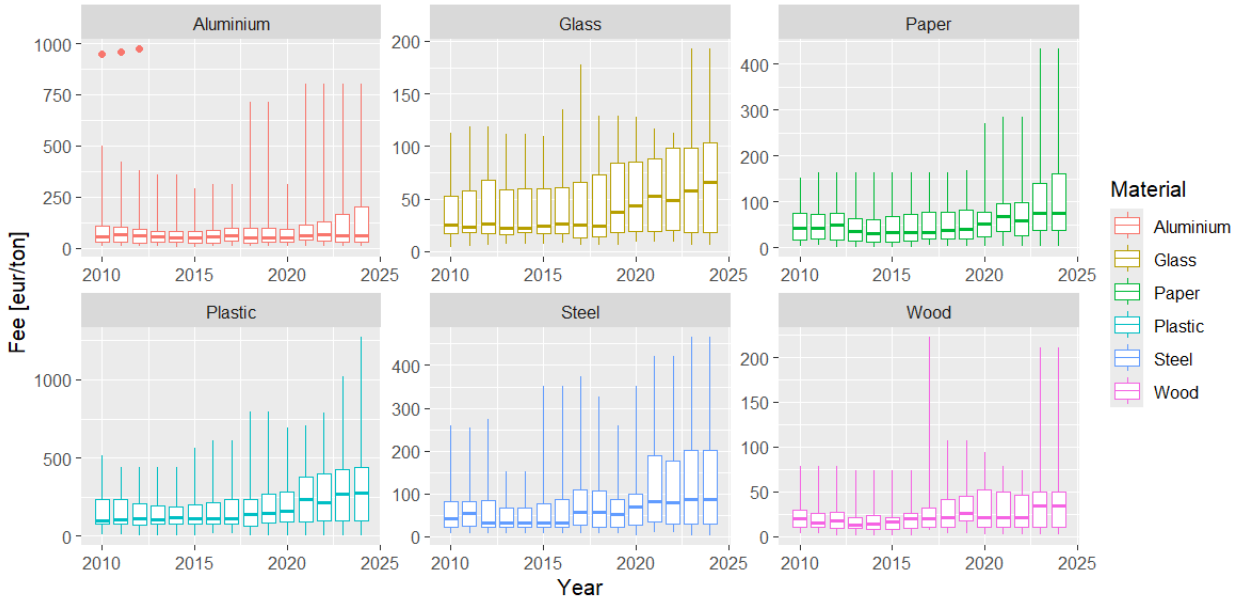


Figure 2: *Values of EPR fees by year and material*

2.2.2 Classification of EPR schemes' characteristics

In this update, we maintain the classification framework for Extended Producer Responsibility (EPR) systems initially outlined in Croci et al. (2021). This classification, based on a review of the literature and particularly drawing from EXPRA's annual reports, identifies key characteristics of the systems in which Producer Responsibility Organizations (PROs) operate. The framework considers four main aspects: market structure, operational responsibility for collection and recycling and market dimension.

- **Market Structure:** EPR compliance schemes can function under either a non-competitive or competitive model. In the former, only one PRO operates as the sole compliance scheme in its market segment, whereas in the latter case multiple PROs operate in competition among them

within one market segment. Cases where multiple PROs operate with distinct scopes—such as separate responsibilities for household vs. commercial/industrial packaging waste (e.g., Belgium and Austria) or different material streams (e.g., Ecovidrio and Ecoembes in Spain) — are not classified as competitive under this framework.

- **Operational Responsibility:** Household waste collection and recycling can be managed by local authorities ("L.A."), private contractors under an EPR framework ("EPR"), or a combination of both ("L.A. and EPR").
- **Market Dimension:** PROs and national EPR schemes are categorized based on the population they serve: "Small" PROs cover fewer than 3.5 million inhabitants, "Medium" PROs serve between 3.5 and 10 million, and "Large" PROs operate in systems exceeding 10 million inhabitants.

This classification provides a standardized approach for comparing regulatory and operational models across different national contexts.

2.2.3 Costs of Deposit Return Systems (DRS)

Cost of the twelve DRS schemes operating in the EU from 2016 to 2022 is collected from the Global Deposit Book (2016, 2018, 2020, 2022). Figure 3 presents a breakdown of handling fees and administrative costs in Deposit Return Systems (DRS) across different materials and years. It includes handling fees for materials collected through **Reverse Vending Machines (RVMs) with compaction**, which, despite reducing storage and transport costs, tend to be higher than **manual collection fees** due to the significant investment required for RVM infrastructure and ongoing operational maintenance costs. **Administrative costs per unit**, which cover system management and reporting expenses, are funded through a specific EPR fee. These costs generally range between **0 and 5 euro cents per unit**, except for **Finland and Denmark for glass packaging**, where administrative costs are notably higher, ranging between **10 and 50 euro cents per unit**. It is important to highlight that Deposit Return System (DRS) fees typically do not cover costs related to coordination, communication, and reporting. In contrast, Extended Producer Responsibility (EPR) fees collected by Producer Responsibility Organizations (PROs) generally do include these cost categories. As a result, the comparability of Key Performance Indicators (KPIs) across

different schemes is affected by the varying scope of costs incorporated into their respective fee structures.

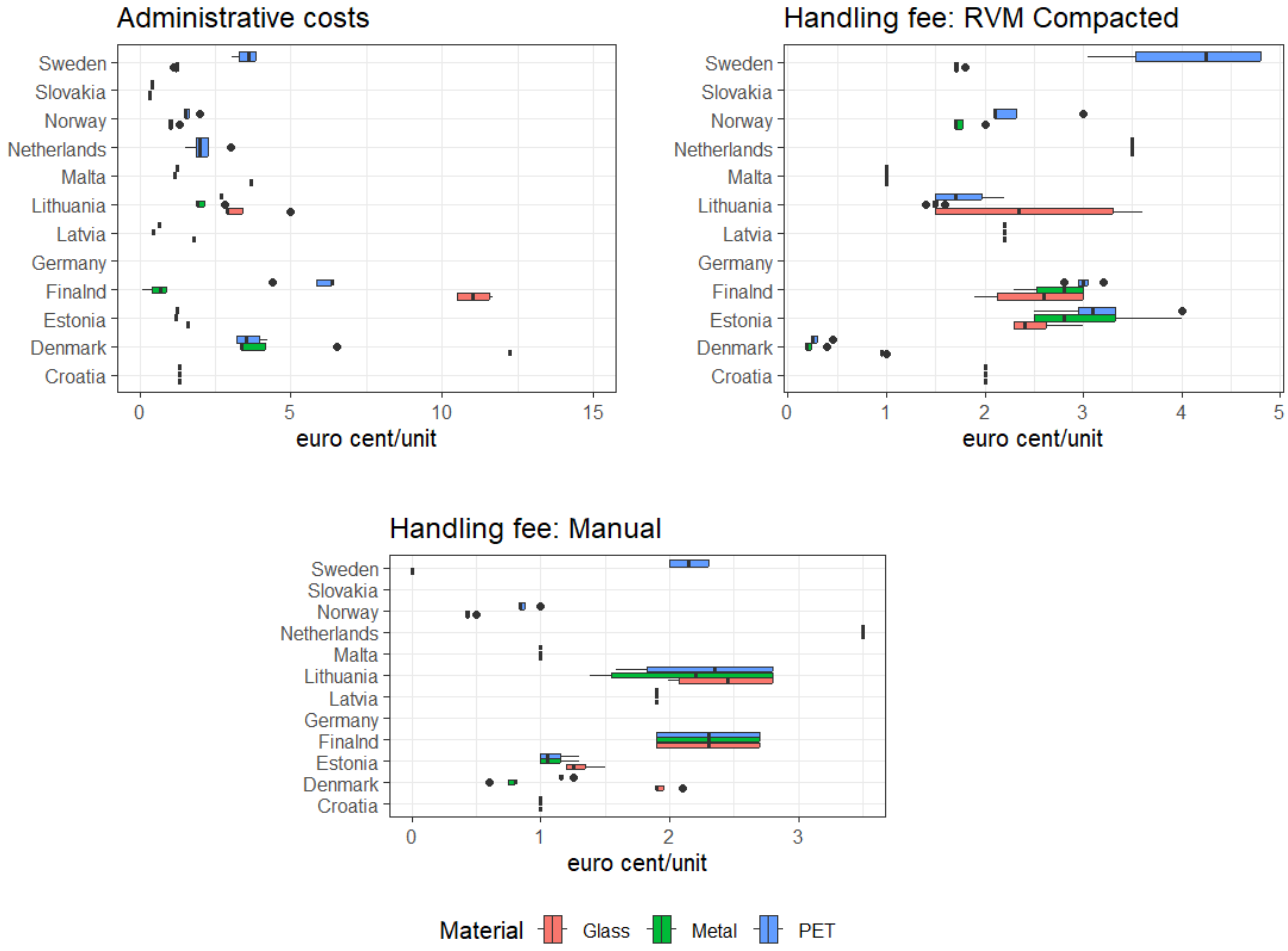


Figure 3: *Values of DRS costs by country*

2.3 Computation of KPI

2.3.1 Performance of PROs

To quantitatively assess the overall efficiency of Producer Responsibility Organizations (PROs), we identified two key performance indicators (KPIs) for benchmarking.

- Recycling KPI: The first indicator is the normalized recycling rate (henceforth, *recycling KPI*), defined as:

$$norm(\frac{Recycled_{m,t}}{PoM_{m,t}})$$

This measures the proportion of placed-on-market (PoM) material that is ultimately recycled.

- Cost KPI: The second indicator is the normalized cost per ton of recycled material (henceforth, *cost KPI*), defined as:

$$norm[\frac{(Fee_{m,t} * PoM_{m,t})}{Recycled_{m,t}}]$$

where:

- m = material type
- t = year
- **Fee** = average fee charged by PROs
- **PoM** = placed on market (tons)
- **Recycled** = tons of material recycled

This KPI captures the economic efficiency of PROs by incorporating both the mean fee charged per ton of material placed on the market, and the actual quantities recycled. Unlike the EPR fee alone, the cost KPI accounts for how effectively fees translate into recycling performance.

Both KPIs are normalized using min-max scaling, a method that rescales values within a range from 0 (least efficient PROs) to 1 (most efficient PROs). This ensures that both indicators contribute proportionally to the final assessment. The KPIs are computed both at an aggregate

level (across all materials) and for individual material types, allowing for a detailed assessment of PRO efficiency.

2.3.2. Performance of DRS

In addition to the PRO efficiency evaluation, we applied the same set of KPIs to assess the performance of Deposit Return Systems (DRS), with some key differences in how the cost efficiency is computed. For both systems, the recycling rate KPI is calculated in the same way, by normalizing the ratio of recycled material to the total placed on the market (PoM), ensuring consistency across systems. However, the cost KPI for DRS differs slightly: it is computed as the sum of the handling fee and administrative costs (covered by the EPR fee), multiplied by the units placed on the market, and then divided by the units recycled. This formula ensures that the cost KPI for DRS matches the one used for PROs, enabling a direct assessment of cost efficiency between the two systems:

$$norm[\frac{((Hfee + EPR\ fee)_{m,t} * UnitsPoM_{m,t})}{Recycled_{m,t}}]$$

Additionally, the cost efficiency KPI for DRS considers all materials covered by the DRS in a given country, offering a comprehensive view of the system's financial performance across different material streams.

Moreover, the handling fee in the DRS cost KPI is calculated as a weighted sum of the fees associated with different collection methods. Specifically, it accounts for both manual collection fees and Reverse Vending Machine (RVM) compacted collection fees, weighted by the share of material collected through each method. This approach reflects the varying costs associated with different collection infrastructures, as manual collection typically incurs higher labor costs, while RVMs involve initial investment but lower per-unit handling costs. By weighting these fees according to their respective shares in the total material collected, the cost KPI more accurately represents the actual financial burden of operating a DRS, ensuring comparability across different system designs and collection models.

The value of the units placed on the market ($UnitsPoM$) is computed based on reported data on the volumes of packaging sold in the countries (EGEN-PNO, 2023) and assuming a uniform

weight by unit for the different material types. While specific average weights for packaging included in DRS across Europe are not readily available, general estimates for standard beverage containers assumed in this study are the following: PET Plastic Bottles: An average PET bottle weighs approximately 25 grams; Metal Cans: An average 330 ml aluminum can weigh about 13-15 grams. Glass Bottles: A typical 330 ml glass bottle weighs around 200-250 grams. Note that the average weights of these containers can vary based on factors such as beverage type, container size, and design.

2.4 Evaluation of taxation schemes

A qualitative assessment was conducted focusing on Lithuania, Latvia, Hungary, and Croatia, where packaging waste taxation operates either as an alternative to or in combination with Extended Producer Responsibility (EPR) schemes. The analysis draws on quantitative data from the EU Commission Tax Datasets and evaluates each country's scheme based on four key criteria: (i) the types of packaging materials subject to taxation, (ii) the complementarity with EPR schemes for the same material types, (iii) the structure of the tax rate, and (iv) the revenues generated. Notably, the study excludes product-specific levies such as those on plastic bags, single-use plastics, as well as VAT and excise duties. Due to significant differences in the design and implementation of these taxation instruments, it was not possible to define a harmonized Key Performance Indicator (KPI) for cross-country comparison. However, cost and performance KPIs were identified for Hungary and Croatia, where the scope and transparency of the public taxation schemes allowed for a more detailed evaluation. In contrast, the limited coverage and data availability in Lithuania and Latvia restricted the depth of quantitative analysis for these countries.

2.5 Assessment across packaging waste management schemes

To provide an overall assessment of the recycling effectiveness and cost efficiency of different compliance schemes, we use KPI-based quantification for both dimensions. This analysis is carried out despite the significant differences in the scope of collected packaging waste and the collection modalities between PROs, DRS and public tax-based systems, to offer a broad comparative assessment. These differences should therefore be considered when interpreting the results.

The methodology used to compute the KPIs for each compliance scheme has also been applied to comparative analysis, with minor adjustments to account for scheme-specific differences. First, for each PRO, each DRS system, and for the case of Croatia and Hungary, which represent the only two taxation system covering the full scope of packaging waste, we calculated the average recycling rate of the materials managed by the respective schemes. Second, we calculated the average collection cost per ton of recycled material. After averaging over time, we normalized both the cost and recycling KPIs to enable assessment across schemes, despite variations in the types of materials recycled.

When comparing the costs of packaging waste tax schemes with PRO fees, both can be considered proxies for the overall costs of packaging waste management—but with important distinctions. Tax rates, while serving as a funding mechanism, are often designed not solely to cover the costs of managing packaging waste, but also to support broader environmental protection and waste management initiatives. As such, they function only as partial proxies for actual system costs. In contrast, PRO fees tend to more closely reflect the direct industrial costs of managing packaging waste, particularly when these organizations are required to finance the full cost of collection, sorting, and treatment. However, the extent to which PROs' fees capture true system costs varies by country, depending on national regulations and the specific cost coverage obligations imposed on PROs.

While this comparative framework enables a high-level benchmarking of different packaging waste management schemes, it comes with certain caveats. The harmonization of indicators may oversimplify some operational and contextual nuances, such as national policy environments, consumer behavior, or market structures for specific materials. Moreover, normalizing KPIs across systems with inherently different targets and infrastructures may introduce distortions in the interpretation of relative performance. Nevertheless, the approach offers valuable insights by identifying broad trends and relative efficiencies across systems. It supports evidence-based discussions on policy design and provides a foundation for more detailed follow-up analyses tailored to specific contexts or materials.

3. Results

3.1 Performance of PROs

The recycling KPI and cost KPI are examined together across different PROs to assess potential trade-offs between higher costs and recycling performance. The most efficient EPR schemes remain those in the first quadrant, where both a high recycling KPI and a high cost KPI (indicating lower costs) are observed, while the least efficient systems cluster in the third quadrant. Overall, most PROs demonstrate relatively strong performance when considering the combination of the two KPIs. Figure 4 illustrates the recycling performance and cost efficiency of various PROs across different countries on average over the period 2015-2023, categorized by their size (Small if population served is below 5 million, Medium if population served is between 5 and 10 million, and Large if population served in above 10 million) and their market of operation (all packaging, only domestic or only industrial).

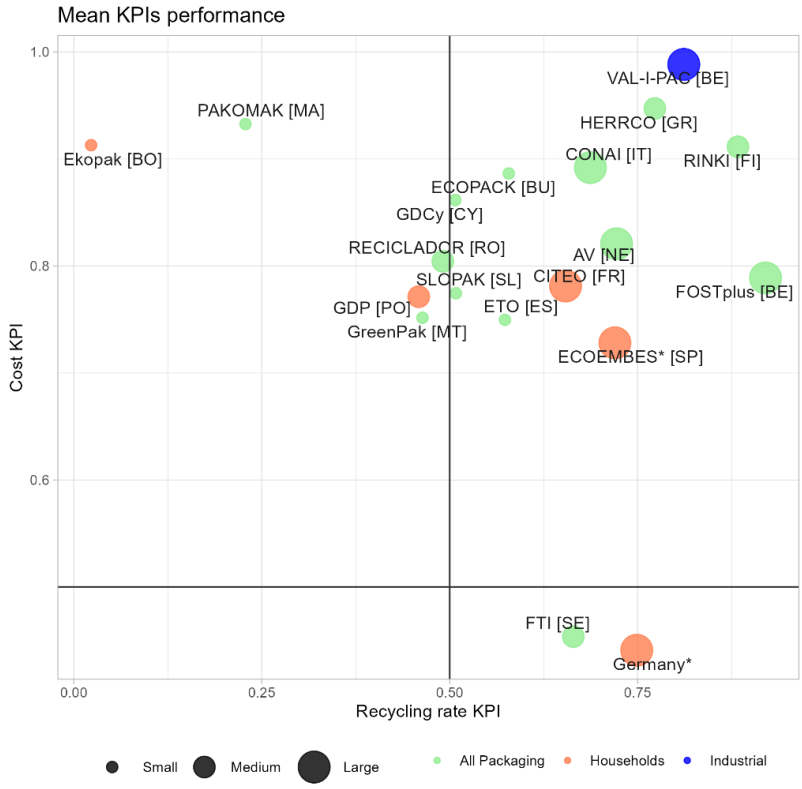


Figure 4: *Average KPI values (2015-2023) by PRO, all materials*

(data for Ecoembes includes results also for the glass stream from Ecovidrio to enale comparability across PROs)

The Recycling Rate KPI varies significantly, with the highest scores observed in Finland (RINKI) and Belgium (FOSTplus), while Bosnia and Herzegovina (Ekopak) and Macedonia (PAKOMAK) have the lowest recycling rate KPI. The Cost KPI, where lower values indicate higher costs, reveals substantial variation as well. Sweden (FTI) and Germany (based on DGP fees and country level-recycling rates) exhibit the least cost-efficient performance, whereas Greece (HERRCO) and Bosnia and Herzegovina (Ekopak) show lower costs. Notably, larger PROs tend to achieve better recycling rates while maintaining relatively lower costs, benefiting from economies of scale, with Italy (CONAI) and France (CITEO), displaying comparatively lower costs. The findings continue to position CONAI among the best-performing PROs, particularly as for the cost KPI, meaning it achieves similar recycling rates with greater cost efficiency. Figure 5 illustrates the relationship between recycling performance and cost efficiency across different PRO size groups (Small, Medium, and Large) over two time periods (2015–2019 and 2020–2023).

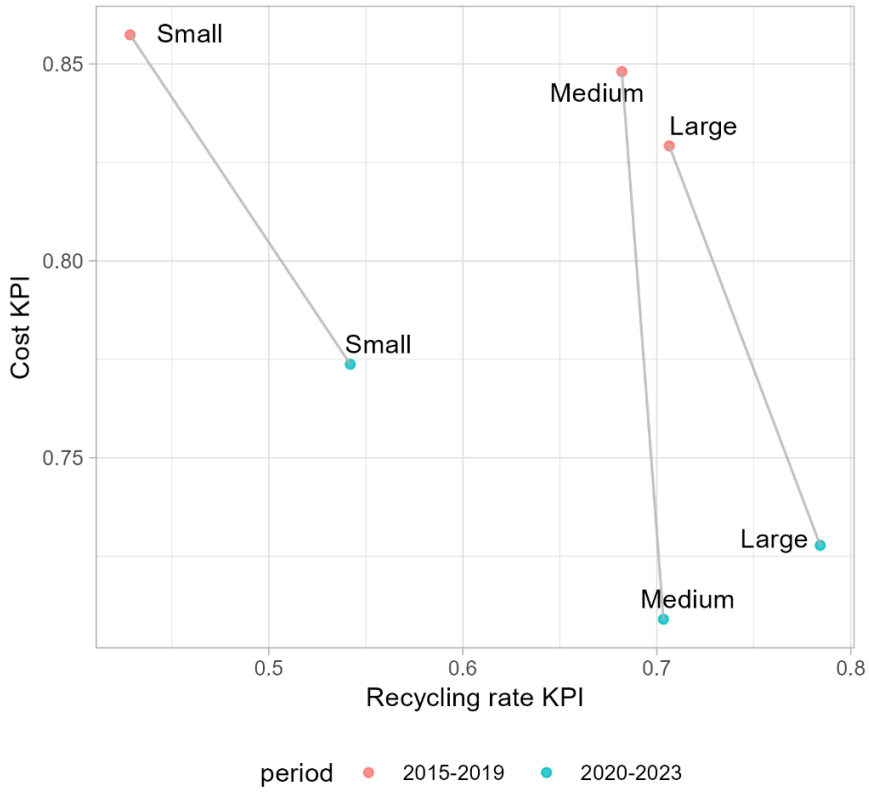


Figure 5: *Average KPI values by time period and PRO dimension, all materials*

The results indicate an overall improvement in recycling performance, with PROs in the Small and Large groups achieving higher Recycling Rate KPIs in the most recent period. However, the cost KPI has declined across all groups, indicating that costs have increased over time. This trend is largely driven by rising fees, particularly for plastic packaging, which has seen higher compliance and recycling costs (see analysis of material-specific KPIs in the next sections). Despite these cost increases, larger PROs continue to perform better overall, benefiting from economies of scale that enable higher recycling rates while maintaining relatively lower costs compared to smaller systems. While smaller PROs have shown significant improvement in recycling performance, they still operate at a relative cost disadvantage.

Figure 6 presents the assessment of key PROs across major European countries, highlighting differences in recycling performance and cost efficiency.

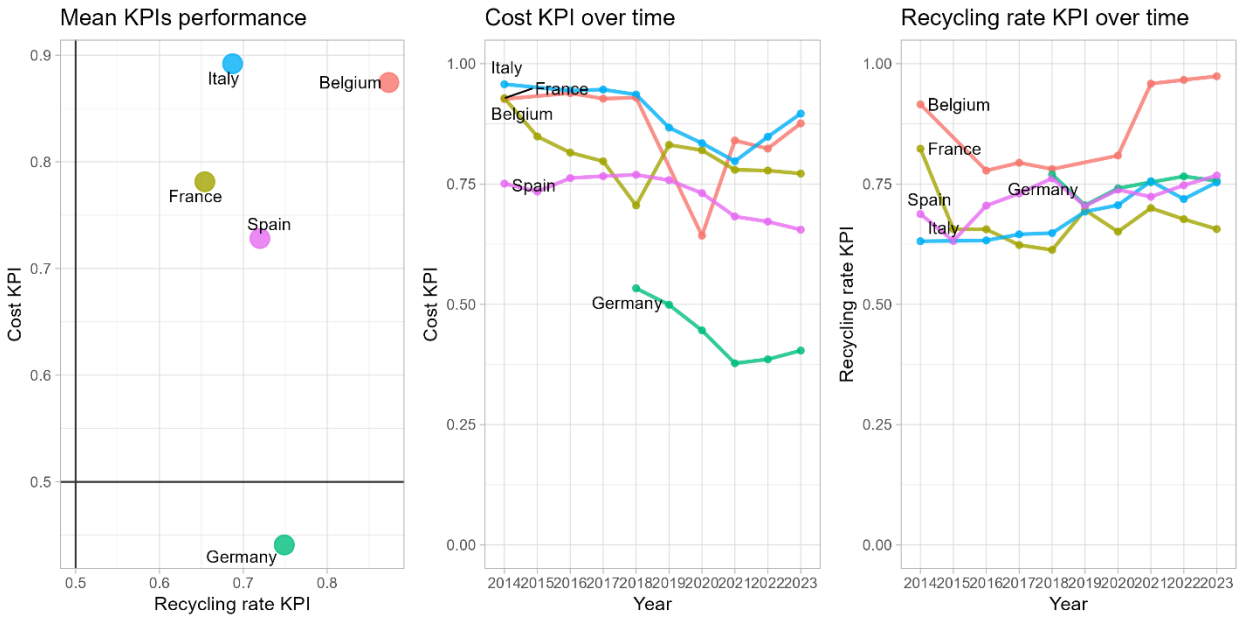


Figure 6: *Average and time-specific KPI values by large PRO, all materials*

Belgium achieves the highest recycling KPI, while maintaining a relatively efficient cost structure. Spain, France, Italy and Germany all demonstrates a relatively similar and strong recycling performance. On the other hand, the performance as for the cost KPI is more heterogeneous, with Italy and, by a close margin, Belgium being the two countries with higher cost KPIs, followed by France and Spain. Germany emerges as the most expensive system by a large gap. The evolution of the cost KPI over time shows that despite all large countries have experienced reductions in the

score over 2019-2023, some of them (Italy and Belgium) have reversed this downward trend in the most recent years (2022-2023).

The assessment between PROs grouped by the competition level aligns with the findings of Croci et al. (2021), showing that non-competitive PROs generally outperform their competitive counterparts in recycling effectiveness, especially when all packaging materials are considered. While this update does not include the regression analysis from Croci et al. (2021), the benchmark analysis confirms that "Non-competitive" PROs typically achieve higher recycling rates while maintaining similar cost efficiency (Figure 7). This is evident in their consistent positioning in the upper-right quadrant of the recycling KPI scores, both on average and over time. Interestingly, the trend observed in the cost KPI has remained similar across the entire sample, suggesting that while the effectiveness of collection may be influenced by the competitive structure of the EPR scheme, the recent increase in costs seems to be driven by factors unrelated to competition.

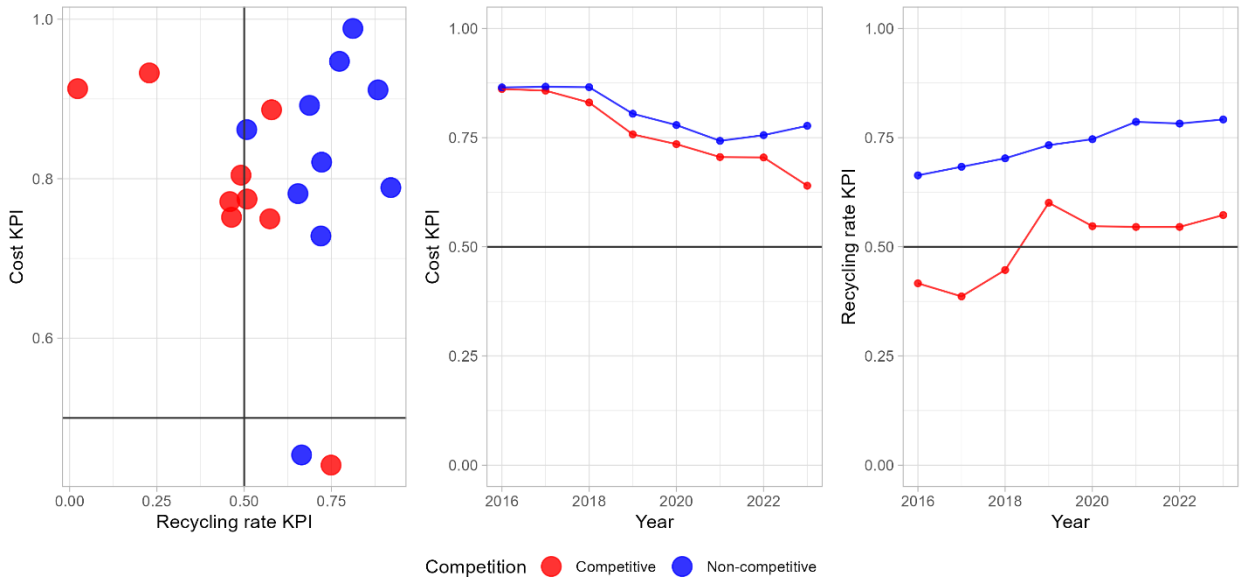


Figure 7: *Average and time-specific KPI values by competition group, all materials*

Another useful approach to explore performance differences among PROs is to classify them based on the actor that holds operational responsibility for packaging waste collection. This categorization reveals a consistent trend: PROs that rely on local authorities, either independently or in partnership with the PRO, tend to achieve higher recycling rates than those where the PRO alone is responsible for collection operations (Figure 8). This suggests that the involvement of local authorities, who typically possess stronger

logistical capacity, local knowledge, and established waste collection infrastructure, may contribute to more effective material recovery. Notably, the gap in recycling rate KPIs between these two groups has widened in recent years. PRO systems based on shared or local authority-led operational responsibility have shown a more substantial improvement in the recycling KPI performance over time, indicating that collaborative models may offer greater efficiency and responsiveness in achieving recycling targets.

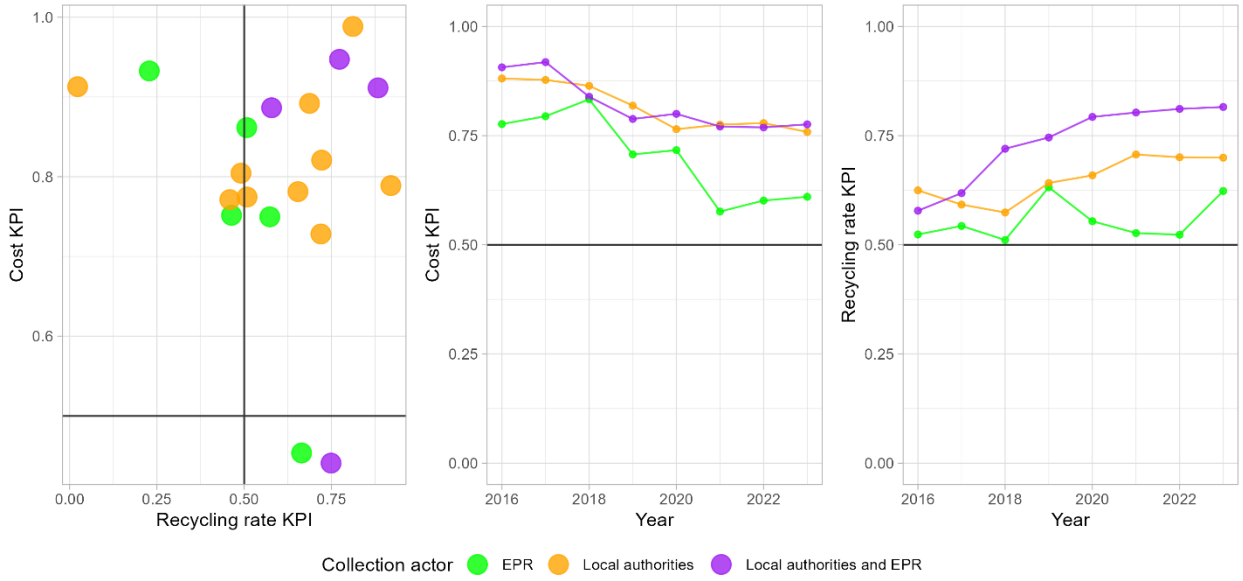


Figure 8: *Average and time-specific KPI values by responsibility of collection, all materials*

Performance by Material

In this section we present an assessment of key performance indicators (KPIs) across the four main packaging materials (paper, plastic, glass and metals), highlighting differences in both performance and cost efficiency among PROs. In the case of Glass recycling, most PROs achieve high scores in the cost KPI, with the exception of GreenPak (Malta), which has a notably lower score. However, the recycling rate KPI exhibits greater variability, indicating differences in efficiency across PROs. For metals' recycling, the pattern is relatively similar with respect to the glass stream: while cost efficiency remains relatively stable, the actual recycling performance differs more substantially across PROs. As for the paper stream, the recycling rate KPI tends to be more homogeneous across PROs than as for glass and metals. In all these materials, several PROs achieve significantly higher recycling KPI and cost KPI scores compared to the rest. Plastic

recycling stands out as the most heterogeneous category, with both the cost and recycling rate KPIs varying widely among PROs. This suggests significant differences in how organizations manage plastic waste in terms of both financial efficiency and recycling effectiveness.

Figure 9: *Average KPI values by material, all PROs (left) and only large (right) PROs*

Figure 10 highlights significant differences in recycling performance among large Producer Responsibility Organizations (PROs) in Belgium, Germany, Italy, and Spain, with notable variation across material streams. Fost-Plus consistently emerges as a strong performer, particularly for glass, paper, and metals. For glass packaging, recycling performance is relatively consistent across countries, except for Belgium's PRO, which shows a substantially higher recycling KPI. In the case of metals, recycling and cost KPIs are broadly similar across PROs, except for Germany, which stands out for its notably low cost KPI. The paper stream presents greater heterogeneity, especially in cost performance, with Italy's CONAI recording the highest cost KPI among the group. Plastic packaging shows the greatest variation in both cost and recycling KPIs. CONAI and ECOEMBES report the highest cost KPIs, though it's important to note that Belgium's VAL-I-PAC, which focuses on commercial and industrial packaging, is excluded from direct comparison in this stream. ECOEMBES also achieves the highest recycling KPI for plastic, while the remaining PROs display relatively similar performance levels. Overall, these differences underscore the influence of system design, material-specific strategies, and operational roles on PRO effectiveness.

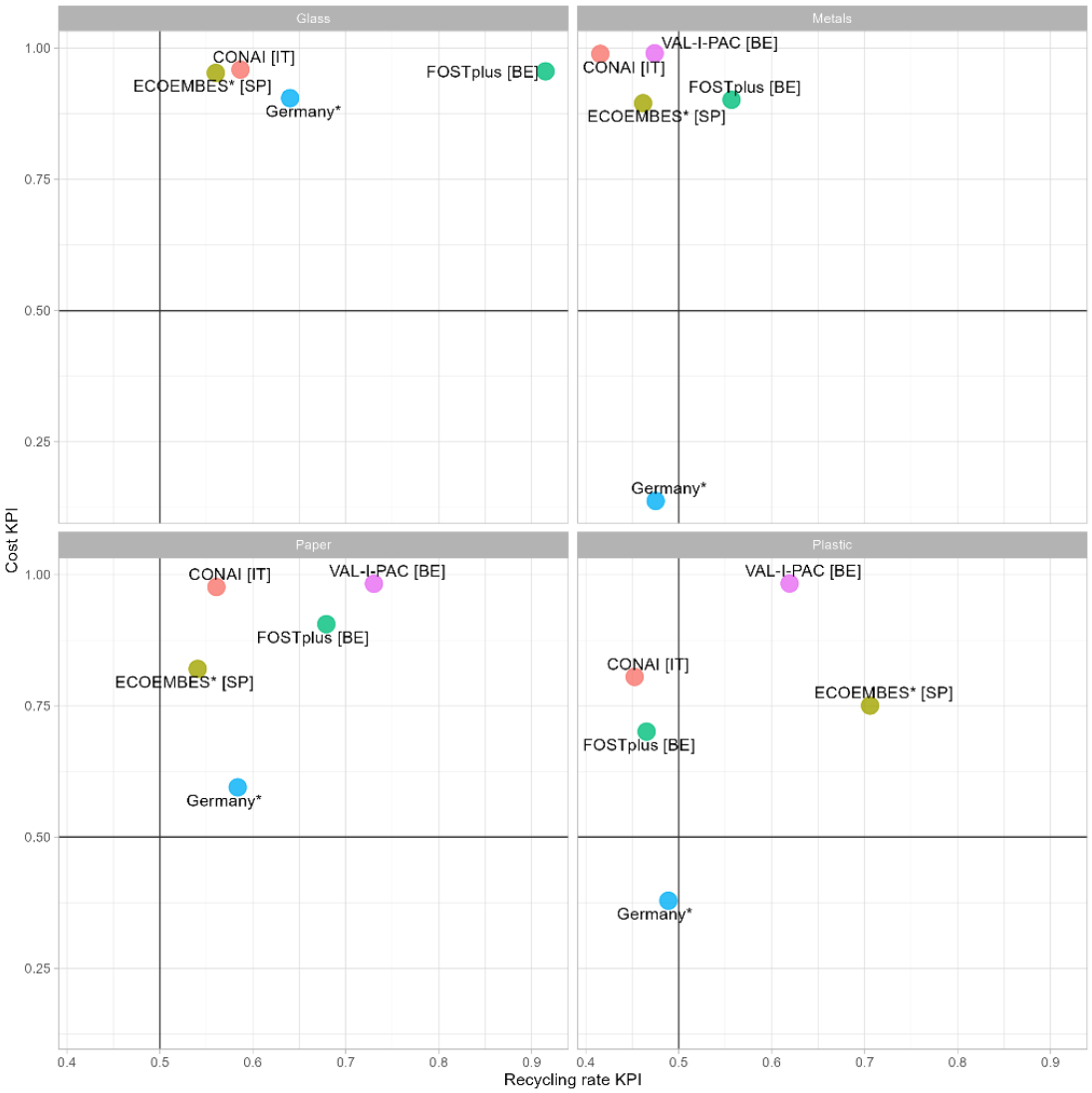


Figure 10: *Average KPI values by material, only large PROs*

Figure 11 illustrates the differences in KPI performance across dimensional groups for two time periods (2015–2019 and 2020–2023), complementing the aggregated analysis presented in Figure 5. When disaggregated by material, the data reveals that the overall decline in the cost KPI in the more recent period is primarily driven by changes in the plastic stream. Notably, only large PROs have achieved both a reduction in costs and an improvement in recycling performance for plastics, suggesting greater efficiency gains in larger-scale systems. In contrast, small and medium-sized PROs show an increase in cost without a corresponding improvement in recycling performance for this material, on average across the two periods. For other materials, particularly glass and paper, the data indicates an upward trend in recycling performance, with relatively stable cost KPIs. This suggests that improvements in collection systems and

operational practices over the past three to four years have contributed to better outcomes without significantly increasing costs.

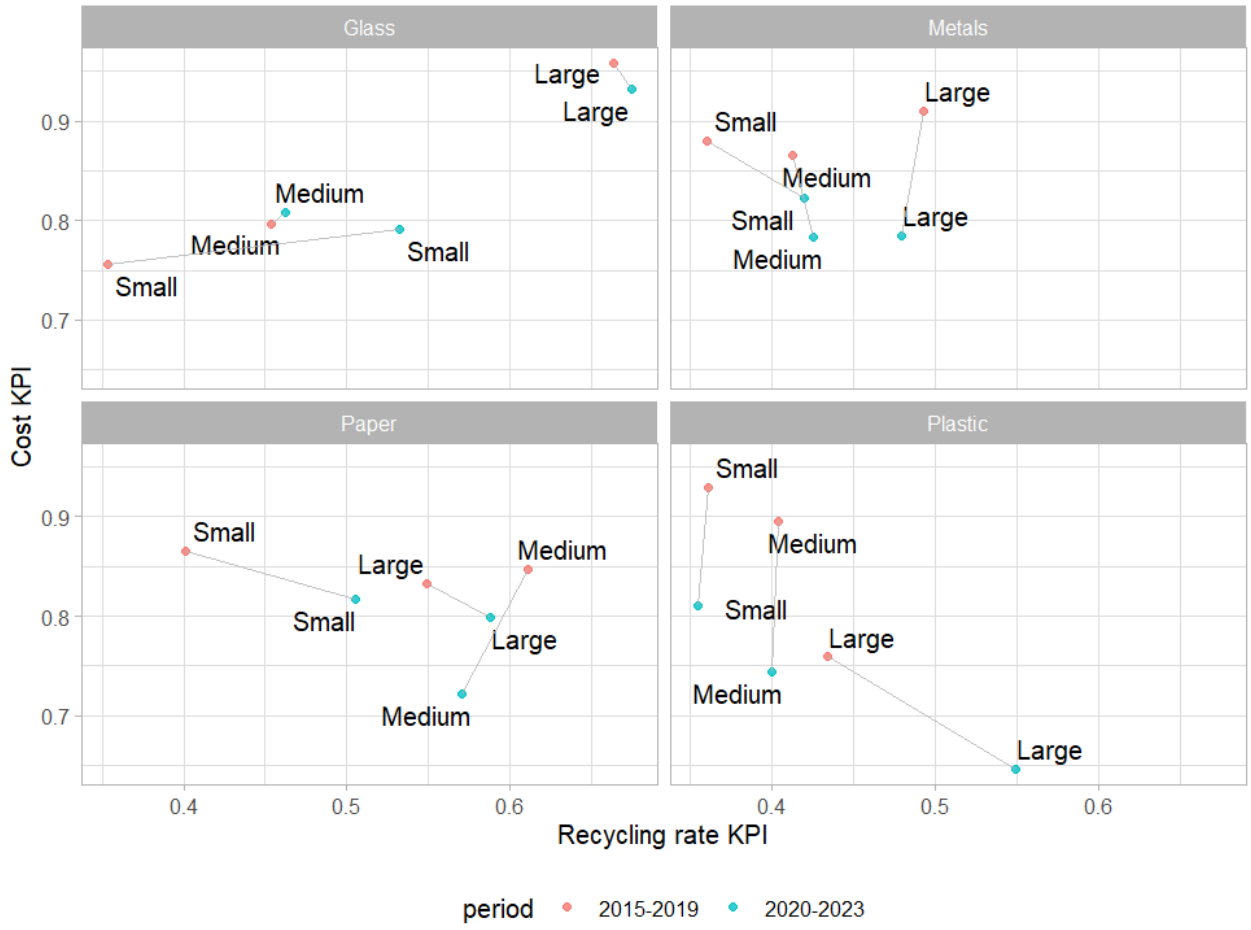


Figure 11: *Average KPI values by period and dimension group for each material.*

3.2 Performance of DRS

This section provides the assessment of the KPI scores of the DRS schemes. Figure 12 shows the cost and performance efficiency of across various countries, focusing on material groups and population size. The results indicate notable variations in both the cost-efficiency (represented by the cost KPI) and performance (represented by the performance KPI) of these systems. The DRS in Norway, Denmark and Finland are the system that tends to show a relatively balanced relationship between cost and performance. On the other hand, countries with smaller populations such as Estonia and Lithuania score in the low-end of the recycling KPI. Estonia in particular show low levels of recycling KPI as well as cost KPI, an effect that may be due to the small size of its market. The Swedish DRS furthermore appears as a relatively less effective and efficient system if compared to the other countries in the Northern EU region. Finally, Netherlands has a very effective DRS system, since its DRS system only manages PET, enabling higher collection rates than other systems covering also metal and glass packaging.

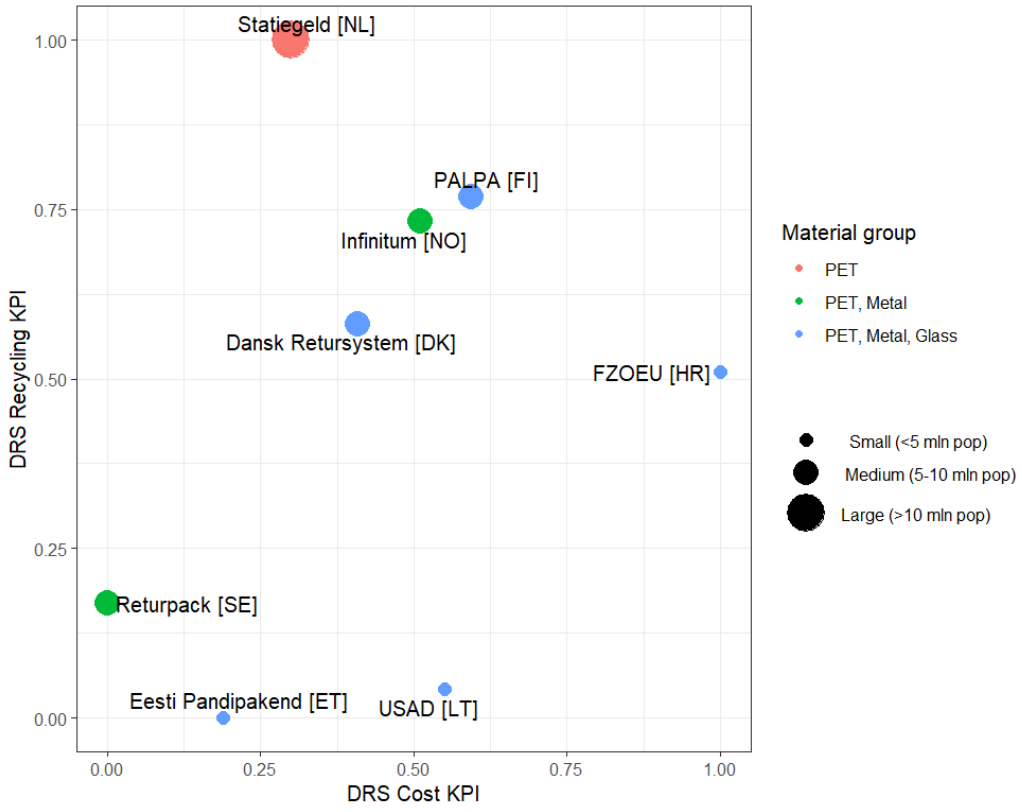


Figure 12: *Average KPI values of DRS schemes*

An interesting trend emerges when looking at the mean deposit fees represented in Figure 13. Countries like Finland, Denmark, Norway and the Netherlands, with a mean deposit above 20 euro cent, show high performance efficiency (higher than 0.50) across all material groups, indicating that higher deposit fees may correlate with better performance in recycling. Estonia, Croatia, Lithuania and Sweden on the other hand all exhibit lower recycling KPI and a deposit of 6-15 euro cent. However, this trend seems to exhibit a saturation effect: while deposit fees higher than 10 euro cent can improve recycling performance, increasing the deposit further from 20 euro/cent yields diminishing or zero returns in terms of recycling effectiveness.

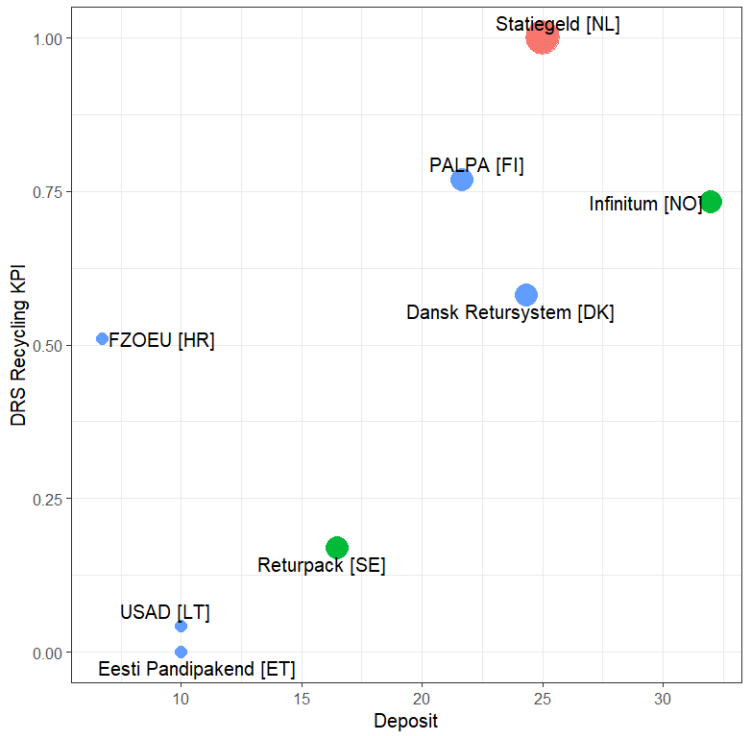


Figure 13: *Average recycling KPI values of DRS schemes and deposit values*

By inspecting the mean KPI levels, we do not find a significant effect of the material groups handled and the system's efficiency or effectiveness.

Figure 14 shows the evolution over time of the KPIs for each DRS system, highlighting that some counties have become more cost-efficient over time (Norway, Estonia) while others have reduced their efficiency (Finland, Sweden, the Netherlands). As for the effectiveness, the systems that

begun their operation in the most recent years (Estonia and Lithuania) have rapidly increased their recycling KPI over the period from 2016 to 2020.

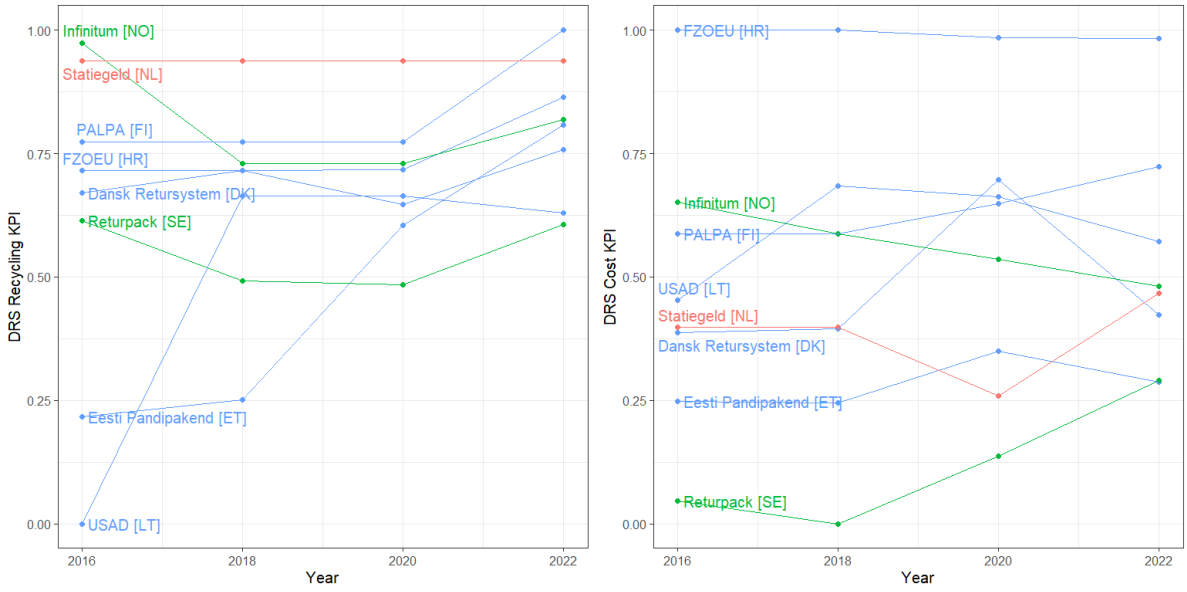


Figure 14: *Time-specific KPI values of DRS schemes*

3.3 Analysis of Packaging Waste Taxation Schemes

The main information collected for each tax scheme can be found in Table 1:

Table 1: Main features of the packaging waste taxation schemes in selected EU countries

Country	Name	Role in waste management system	Tax Basis	Tax Rate structure	Taxation revenues
Lithuania	Tax on pollution	Complementary to PROs	Glass, Paper and Plastic (only non-recyclable)	Glass: 0.395 €/kg, Paper: 0.188 €/kg Plastic: 0.875 €/kg	NA
Latvia	Natural resource tax	Complementary to PROs	Bioplastic, composite cardboard, polystyrene Foam, Plastic bag, Plastic recyclable not recycled or recovered. Plastic non-recyclable not recovered.	Bioplastic: 0.24 €/kg; Composite cardboard: 1.25 €/kg; Polystyrene: 2.2 €/kg; Foam: 24.4 €/kg; Plastic bag: 1.5/4.8 €/kg; Plastic recyclable but not recycled / recovered: 0.8 €/kg Plastic non-recyclable not recovered:1.25€/kg.	NA
Hungary (until 2022)	Environmental Protection Product Charges	Alternative to other schemes (PRO, DRS)	All packaging	Varying depending on packaging.	~100 mln
Hungary (2023)		Complementary to PRO	Plastic carrier bags (biodegradable and non)	4.21 €/kg (0.7 €/kg is biodegradable)	NA
Croatia	Environmental Protection and Energy Efficiency Fund	Alternative to PRO. Complementary to DRS.	All packaging	Varying depending on packaging.	~12 mln

Lithuania applies a tax on pollution that specifically targets non-recyclable packaging materials. The taxation applies to glass, paper, and plastic, with rates set at 0.395 €/kg for non-recyclable glass, 0.188 €/kg for non-recyclable paper, and 0.875 €/kg for non-recyclable plastic. This approach directly links the tax burden to the recyclability of materials, discouraging the use of packaging that cannot be reintegrated into the recycling stream. Additionally, Lithuania operates an Extended Producer Responsibility (EPR) system through several PROs (**Žaliasis taškas**, the largest PRO in the country), which though their operation ensure compliance with packaging waste management regulations and works alongside taxation policies to improve recycling efficiency.

Latvia implements a natural resource tax covering a wide range of packaging materials, including bioplastics, composite cardboard, polystyrene, foam, and plastic bags. The tax structure varies significantly, with rates ranging from 0.24 €/kg for bioplastics to as high as 24.4 €/kg for foam. The tax on plastic bags is differentiated, with rates set at 1.5 €/kg and 4.8 €/kg depending on specific conditions. Additionally, recyclable plastic that is not actually recycled or recovered is taxed at 0.8 €/kg, while non-recyclable plastic that is not recovered faces a higher rate of 1.25 €/kg.

In Croatia, the Environmental Protection and Energy Efficiency Fund plays a key role in the packaging waste management system by operating as an alternative to traditional Producer Responsibility Organisations (PROs) and in complement to the national Deposit Return System (DRS). The scheme applies to all types of packaging, with tax rates varying depending on the specific characteristics of the packaging material. The scheme generates approximately €12 million in annual revenues, which are reinvested into waste management and environmental protection activities.

The Hungarian system has progressively evolved from one in which the Environmental tax covered several products in substitution from the EPR scheme until 2022, to a marginal role targeting plastic bags in 2023. In 2022, the last year of full operation, all companies were obliged to pay an environmental tax (the "environmental product charge") to the National Tax and Customs Administration. The tax base was the packaging material placed on the market. In case of products produced abroad the importer company is responsible for the charge, i.e. the company who imports, and sells the product in Hungary at the first time, or uses it for their own purposes. Values were unflexible across material types, with a levy of 48 €/ton for paper, glass and metals, while of 140 €/ton for plastic (excluding bags) and combined beverage cartons. On March 14, 2023 a

Hungarian government decree set the detailed rules for the operation of the EPR, regulating that the system would work in parallel to the environmental protection product charge regulations. Nonetheless, all companies are obliged to report the data for the environmental product charges to the National Tax and Customs Administration as well. The fees of the EPR scheme increased with respect to the tax rates, as shown in Figure 11. The narrow scope of application of the taxation scheme from 2023, including only plastic bags, is comparable to other plastic bag taxation schemes implemented across EU.

The quantification of packaging waste costs in Hungary for 2022 and 2023 reveals a significant shift in financial burdens due to the transition from a tax-based system in 2022 to an EPR fee structure in 2023 (see Figure 15 and Table 2). In 2022, the total cost for managing waste across four major materials—Paper, Glass, Metals, and Plastic—was €102 million, with Plastic being the most expensive at €60 million, due to its higher tax rate of €140/ton. However, in 2023, the introduction of much higher EPR fees led to a dramatic increase in costs, rising to €574 million. Paper saw the largest increase, from €28.8 million to €258 million, driven by a substantial rise in the EPR fee from €48/ton to €430/ton. Similarly, the costs for Glass, Metals, and Plastic also surged, with Plastic's cost reaching €235.4 million. This significant rise in costs reflects the policy shift towards encouraging recycling and responsible waste management, although it also raises concerns about the financial impact on producers and consumers due to the higher fees, especially for high-volume materials like Paper and Plastic.

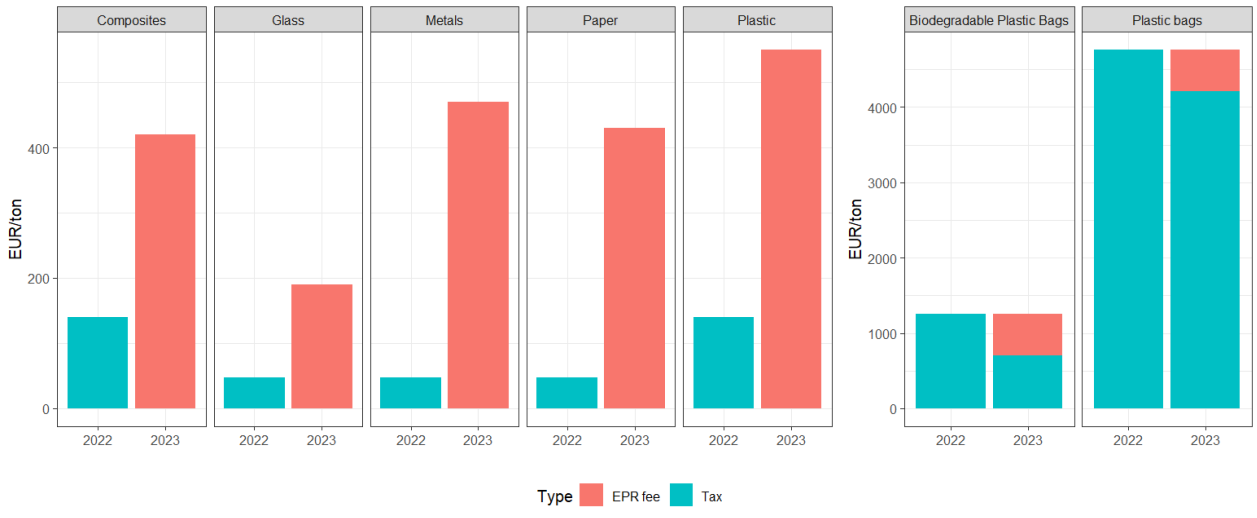


Figure 15: *Change between Tax and EPR fees in Hungary from 2022 to 2023*

Table 2: Change between Tax and EPR costs in Hungary from 2022 to 2023, main materials only					
	Paper	Glass	Metals	Plastic	Total
Tax (€/ton)	48	48	48	140	
EPR fee (€/ton)	430	190	470	550	
Waste generated 2022 (k ton)	600	175	100	428	1303
Cost 2022 (mln €)	28.8	8.4	4.8	60	102
Cost 2023 (mln €)	258	33.25	47	235.4	574
Sources: PRO Europe (2024); Eurostat (2024)					

Integration between Tax and EPR

A key aspect of the taxation schemes analyzed is their relationship with existing Extended Producer Responsibility (EPR) systems. Lithuania's approach focuses on the environmental externalities generated by packaging waste, and is therefore set in parallel to an EPR scheme in which three distinct PROs are responsible of the packaging waste management. By taxing non-recycled materials, the tax scheme is designed to cover a broad spectrum of packaging materials, implicitly accounting for their overall environmental impact rather than financing the waste management operations connected to packaging waste. Latvia implements a natural resource tax that is intended to discourage the use of virgin raw materials in packaging production. This approach targets packaging at its source by influencing the material input, rather than solely addressing waste management downstream. Also in this case, the taxation is set in parallel to an EPR scheme in which five distinct PROs are responsible of the packaging waste management.

Hungary's scheme is the only one that - until 2022 – was aimed at financing the management of the full range of packaging products as an alternative to the EPR, under the broader umbrella of environmental protection. The EPR scheme based on a single for-profit PRO was introduced on July 1, 2023, aligning with EU directives to enhance waste management practices. The system entailed new PRO fees which are significantly higher than the previous EPC rates. Furthermore, despite the introduction of the PRO-based system, companies are still required to register and report data for the environmental product charge to the National Tax and Customs Administration. Businesses must adapt to new reporting and fee payment obligations under the EPR scheme, ensuring timely registration and accurate data submission to the relevant authorities. The effect on the collection and recycling efficiency and effectiveness from the introduction of Hungary's PRO-

based system for packaging waste cannot be evaluated in this report, as comprehensive data post implementation is not yet available.

3.4 Comparative analysis across compliance schemes

The comparative analysis assesses the cost efficiency and recycling effectiveness of the different compliance schemes using normalized KPI indicators. The two dimensions presented in Figure 16, where each scheme is represented according to its average recycling rate KPI (x-axis) and cost efficiency KPI (y-axis), with higher values indicating better performance on both axes. The dimension of the scatterplot represents the average yearly quantities recycled by each type of scheme (mean across the several years and countries considered). This indicator points to the considerable difference in the average size of each scheme, ranging from 1700 kton as for PRO-based systems to 300 kton as for the public tax-based schemes and to around 40 kton as for the DRS. This corresponds to an average dimension of the packaging market managed by PROs much **6 times higher than public-tax** schemes and **43 times higher than DRS**.

DRS, shown in green, demonstrate very high recycling effectiveness. However, this performance comes at the expense of lower cost efficiency. This suggests that while DRS can be highly effective in capturing relatively small quantities of targeted materials (mainly PET, metal, and glass), but also that they tend to involve higher relative costs per tonne collected. Producer Responsibility Organisations (PROs), shown in purple, show a high recycling performance, but with much higher cost efficiency. This suggests that PROs may offer a more cost-efficient solution, albeit with lower recycling rates than DRS systems. The public tax-based system, depicted in orange, achieves similar recycling effectiveness than PRO-based schemes, but with a lower cost efficiency.

These results should be interpreted with caution, as several contextual and structural factors influence performance but are not fully captured by the normalized KPIs: material scope and system design vary across schemes, DRS systems typically focus on high-value, homogenous fractions (e.g. PET bottles), while PROs manage a more diverse and complex waste stream, including household packaging. National context, such as regulatory frameworks, consumer behavior, and logistics infrastructure, significantly affect both cost and recycling outcomes. System maturity and operational scale may also shape performance, some schemes are long-established while others are more recent or limited in scope. Overall, the comparative analysis highlights that DRS systems are highly effective but relatively costly, while PROs offer a more

cost-efficient route with acceptable recycling outcomes, especially when covering broader material scopes. This insight can inform future policy considerations on how to best balance performance targets and economic viability when designing or reforming packaging waste systems.

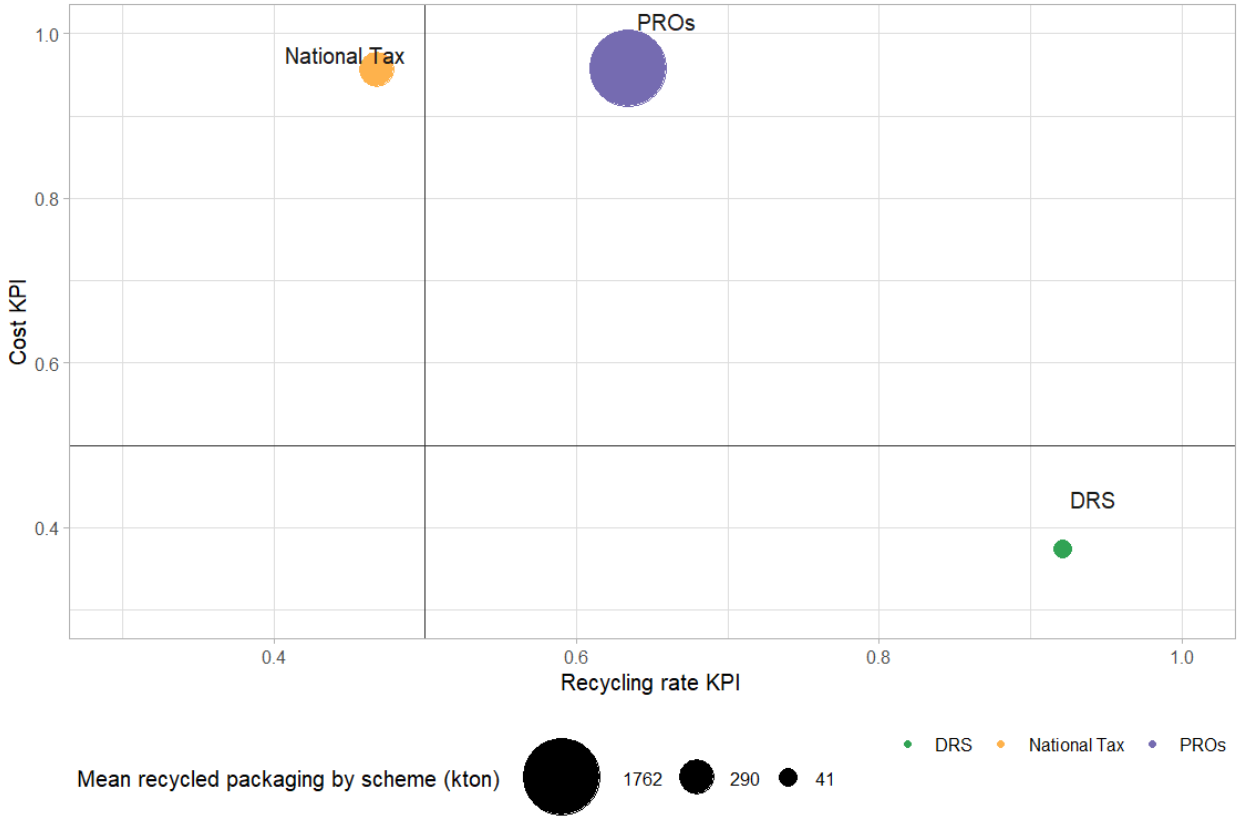


Figure 16: *KPIs across different EPR compliance schemes*

4 Discussion and Conclusions

This study offers a comprehensive, KPI-based benchmarking of packaging waste management schemes across Europe, providing new evidence on the comparative performance of Producer Responsibility Organizations (PROs), Deposit Return Systems (DRS) and public waste management with tax-based financing. By updating and expanding upon the methodology of Croci et al. (2021), the present analysis evaluates the operational efficiency and cost-effectiveness of a wide array of compliance frameworks and introduces a dynamic monitoring system for tracking performance over time. The results reveal important patterns and trade-offs that are highly relevant for policymakers, producers, and waste management practitioners navigating the EU's evolving regulatory landscape, especially under the new Packaging and Packaging Waste Regulation (PPWR).

The analysis confirms the persistence of a trade-off between recycling effectiveness and cost-efficiency within EPR schemes. Larger Producer Responsibility Organizations (PROs) consistently outperform smaller ones in both cost and recycling KPIs, underscoring the benefits of economies of scale. Systems such as CONAI (Italy) and CITEO (France) demonstrate the capacity to maintain high recycling rates while containing operational costs, validating their role as benchmarks for cost-effective compliance. Conversely, smaller or recently established PROs, particularly in Southeast Europe, continue to face challenges in achieving both high recycling outcomes and cost efficiency, often due to fragmented logistics, limited infrastructure, or regulatory uncertainty.

The study also reaffirms the earlier finding that non-competitive PRO systems tend to deliver higher recycling performance than competitive ones, suggesting that centralized systems may better align incentives and streamline operations, especially when managing complex, multi-material waste streams. However, rising costs, particularly for plastics, affect all system types, pointing to broader market trends and regulatory pressures, such as recycled content targets and eco-modulation of fees.

DRS schemes, while delivering the highest results across compliance schemes in terms of collection rates—often exceeding 80% for PET, metal, and glass beverage containers—demonstrate lower cost efficiency. Countries such as Norway, Denmark, and Finland illustrate

well-functioning systems, but the associated cost per ton collected is notably higher than in PRO-based systems. This finding aligns with existing literature and underscores a key policy consideration: while DRS is an effective tool for targeting beverage packaging, its expansion to other material streams may face diminishing returns unless accompanied by cost optimization strategies.

The analysis also suggests a saturation effect concerning deposit values: while moderate deposit levels (10–20 euro cents) appear to enhance collection rates, further increases yield limited improvements. This insight provides a useful benchmark for countries designing or reforming DRS systems. Furthermore, DRS effectiveness appears less influenced by material scope than expected, suggesting that the maturity of the system and public participation may be stronger determinants of success than technical design alone.

The public taxation-based schemes, observed as a stand-alone compliance scheme only in Croatia and Hungary (until 2022), show similar as for the cost KPI, while lower recycling performance. While fiscal instruments can effectively internalize the environmental cost of non-recyclable packaging and influence upstream material choices, they are not substitutes for operational waste management systems pointing to achieve higher recycling rates over time. Hungary's transition from a taxation-only model to a full EPR scheme in 2023 an interesting case for more detailed future analysis: although it resulted in significantly higher compliance costs, it also aligned the country with EU directives and opened the door to more structured and potentially effective waste management practices, potentially improving the recycling rate in subsequent years.

Where taxation is implemented in parallel with EPR—as in Lithuania and Latvia—the two instruments appear to be complementary. Taxes target the environmental impact of materials at source, while PROs ensure downstream collection and recycling. However, the KPI-based analysis conducted in this study could not be performed for the evaluation of the hybrid compliance scheme, due to the lack of disaggregated data on the recycling rates of the specific sub-materials covered by the tax schemes, preventing an evaluation of the role of such integrated approach.

The comparative analysis underscores that no single compliance scheme optimally balances recycling performance and cost-efficiency. DRS systems are unmatched in effectiveness for specific high-value, homogenous materials but remain expensive. PROs offer broader coverage

and better cost-efficiency but face challenges in meeting the highest recycling targets, especially for complex materials like plastics. Taxation, while valuable as a policy lever, is insufficient on its own to drive circular outcomes.

These findings reinforce the need for hybrid systems that leverage the strengths of each compliance approach while mitigating their limitations. Furthermore, policy design must account for national contexts, including infrastructure, market size, and institutional capacity, to ensure cost-effective implementation.

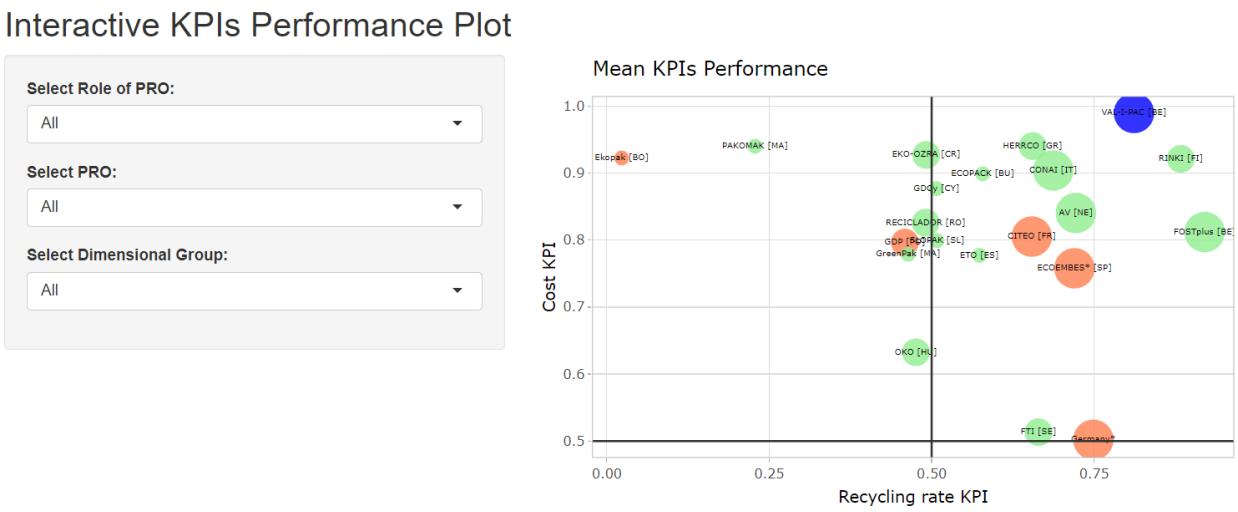
While this study offers a robust comparative analysis, it is not without limitations. The use of normalized KPIs, while enabling cross-country comparability, may obscure contextual differences in waste composition, infrastructure maturity, and data quality. Additionally, the analysis does not yet assess the environmental outcomes (e.g., CO_2 savings, litter reduction) of each compliance scheme, which could complement the economic and operational metrics used here. Future research should explore the integration of environmental impact indicators with cost and recycling KPIs, as well as investigate the socio-economic effects of rising compliance costs on producers and consumers. Moreover, with new data expected from Hungary's EPR scheme in the coming years, follow-up studies could assess how the transition from taxation to EPR affects collection outcomes and system efficiency.

In conclusion, this study contributes to the growing body of evidence supporting the strategic design of packaging waste systems in Europe. By benchmarking performance across EPR, DRS, and taxation models, it highlights key trade-offs and synergies and provides actionable insights for advancing the circular economy through effective, data-driven waste governance. The dynamic KPI monitoring framework introduced in this study offers an important step toward greater transparency and accountability in waste management. By enabling real-time tracking of performance, it supports continuous improvement, facilitates cross-country learning, and aligns with the EU's objectives under the Circular Economy Action Plan.

5 Interactive Dashboards

In order to provide a up-to-date evaluation of PROs and DRS performance over EU countries and time periods, this report includes a set of interactive Dashboards that can be accessed online by the users.

Example of dashboards are presented below:



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